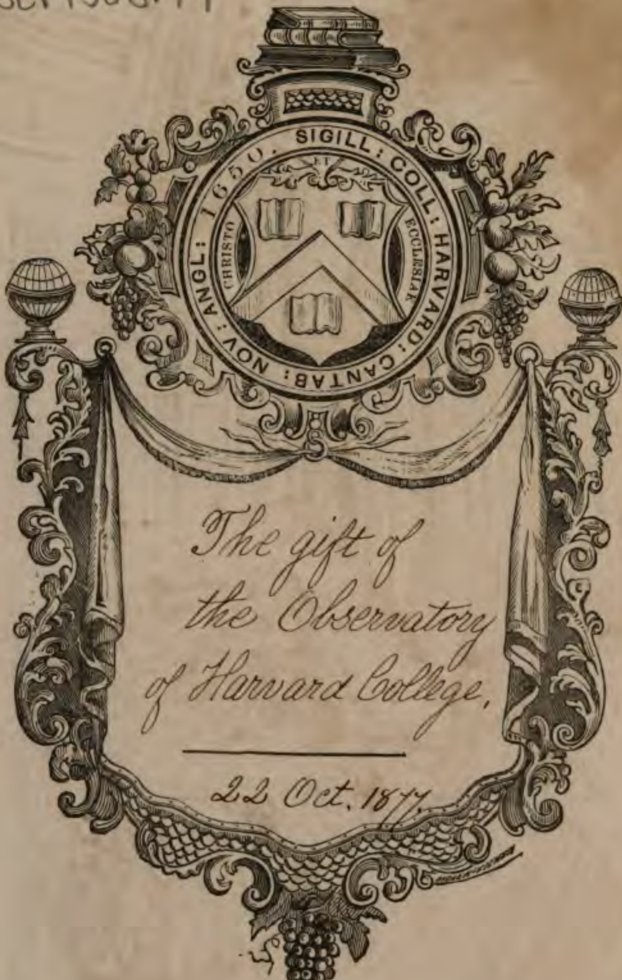
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CHRISTO ET ECCLESIAE

Waldo, Leonard.

STANDARD PUBLIC TIME.

Issued by the Observatory of Harvard College for distribution among those interested in a Common Standard of Public Time throughout New England.

By Leonard Waldo.

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1877, Oct. 22,
Gift of
The Observatory.

STANDARD PUBLIC TIME.

The element of time enters directly or indirectly into every business transaction, and the direct saving of time and money to the commercial community which would accrue from a recognized standard of public time is not to be lightly estimated. In London, the Greenwich Observatory takes the lead in the introduction of standard public time. From it radiate wires to nearly every railway station in England, and at prominent points in the principal cities, clocks regulated from the Observatory, of which we shall say more hereafter, beat second for second with the standard clock at Greenwich. The standard clock in the Observatory at Liverpool, England, controls that in the turret of the Town Hall and one having six dials in Victoria Tower, as well as a number of smaller clocks. At Edinburgh, a number of time-guns and one time-ball have been established, and these are now supplemented by several public clocks controlled by the same system. At Glasgow, Prof. Grant says in 1865, "At present there are ten public clocks in Glasgow controlled electrically from the Observatory, at an average distance of three miles from the controlling clock." There is not a German city of commercial importance which does not receive its standard time from an astronomical observatory more or less distant. In France and Switzerland, the public time is furnished by the government. In our own country, at Boston, the time is sent, every two seconds, from Harvard College Observatory to the prominent jewellers and railroads. From the Dudley Observatory at Albany, the New York Central Railroad obtained its time when Prof. Hough was director. At Washington, several clocks in the department buildings are controlled upon the Jones plan, and a time-ball dropped at noon. Through a recent arrangement with the Western Union Telegraph Company, the Naval Observatory now transmits a single signal at Washington noon, to most of the principal cities west of New York, and drops

a time-ball in New York City. At Cleveland, the time was formerly derived from the Observatory at Hudson, Ohio. At Pittsburg, where there is a most complete system for furnishing public time, one wire leads from the Allegheny Observatory to the stores of the principal jewellers. Beside each regulator is a telegraphic sounder, on which the observatory time is heard constantly ticking. At nine and four, Altoona time, signals are sent to every telegraph office through which the wires of the Pennsylvania Railroad pass, between Pittsburg and Philadelphia; and twenty-three minutes afterwards it is sent as far west as Chicago; and the turret-clock of the City Hall, two miles from the Observatory, is controlled by the same clock. From the Cincinnati Observatory, the time is sent daily by a special telegraph line to the entire Fire Department.

The method ordinarily used by the jewellers and amateurs is inexact. With a transit instrument, mounted on top of his house, or in some convenient spot in his yard, and provided with his chronometer and nautical almanac, the observer takes his position on the first clear night, to bring his instrument into the meridian. He singles out Polaris by means of the two pointers in the Dipper, and, pointing his telescope so that Polaris is bisected in its field of view by the middle micrometer wire, he keeps Polaris steadily on the wire, by moving the instrument bodily until the chronometer denotes the time of the star's transit. With very little regard for the exact levelling of the horizontal axis of the transit, he then aligns a mark of some kind in the meridian, and waits until the next noon-day sun shall give him the opportunity of determining his chronometer error with the mininum of computation. This method can never be adequate, either for the regulation of the better grades of clocks and watches or for furnishing the public time; for our standard of time, like our standards of weights and measures, should be exact. In using the transit instrument in this manner, the jeweller assumes, first, that the east and west axis is truly horizontal; second, that its bearings are perfectly symmetrical, and symmetrically placed; third, that the line of collimation of the telescope coincides with a line joining the central point of the micrometer with the optical centre of the object-glass, and also coincides with the meridian; and, fourth, that this line is perpendicular to the east and west axis. Now, in reality, even in the most perfectly constructed instruments of our large observatories, all of these sources of error are assumed to exist; and, with each determination of time, a number of observations are made, having in view the object solely of determining the exact amount of each of these errors and the position of the instrument used. Thus,

for instance, the sensitive level which marks the inclination of the east and west axis must be read a number of times during the observations; being turned end for end between each of the readings, so as to eliminate the errors of the level itself. Knowing the value of one division of a level in fractions of a second of arc, the inclination of the east and west axis is thus determined, and its effect on the time of transit of a star can be computed. By reading the level with the telescope axis elevated to different degrees, and afterwards with the axis reversed in its bearings, the approximate shape of the pivots of the instrument can be determined; and by the observations of a series of stars ranging from the extreme north to the extreme south, the deviation of the instrument from the true meridian can be computed. This deviation has two principal components after freeing the observations which are used to determine it from the errors arising from the east and west axis not being truly horizontal, and the bearings not being symmetrical. These components are the errors of collimation and azimuth. Where the mounting is sufficiently steady, the error of collimation may be determined by pointing the telescope vertically downwards towards an artificial mercury horizon. If the east and west axis is truly level, the distance between the wire in the field of view of the transit and the image of the same wire reflected from the surface of the mercury will be twice the error of collimation. If now we free the set of observations referred to from the effects of the errors of level, irregularity of bearings, and collimation, and apply the small correction for aberration, the observations will then give us the error of azimuth, which, in other words, is the angle made with the plane of the meridian by the plane in which the axis of the telescope moves when the east and west axis is horizontal. After introducing these corrections, we will probably have the error of the time-piece employed to within a fifteenth or twentieth of a single second, supposing its daily rate to be a few tenths of a second: although this is not sufficiently exact for the astronomer's uses, it will answer as a public standard. We have referred thus at length to the manner of determining the time employed by jewellers, because we have found it to be a very common belief among them that their time is accurate to within the small fraction of a second. Were they to observe the sun on consecutive days, their clock-rates would probably be apparently very discrepant; and it would seem so for this reason: an error of five-tenths of a second made in the determination of time after a lapse of five days from a previous determination, would affect the rate of a clock but one-tenth of a second per day, if we apply a daily rate thus determined to the error of the clock as found from the

first set of observations; whereas, if observations were made on the second, third, and fourth days, each with a presumable error of half a second, the discrepancies in the clock-rate might be a whole second between any two consecutive days. The point we wish to make is this, that while observations, taken at, say, a week's interval, may give an apparently small variation to the mean rate of the clock, because the errors of a single observation are distributed uniformly over the seven days, yet jewellers cannot be at all certain that the apparent daily variations of the time-pieces sent to them to be regulated do not in part come from the daily variations of their own standard time-piece, which variations presumably tend to destroy each other, as the temperature rises and falls and the barometer varies. The fact is well known that if a time-piece whose error was determined some months back to be small should now show but a few seconds error, it is no proof that the time-piece has not varied twenty times the amount of the few seconds difference which it indicates. And this leads us to remark, that the difficulties of keeping a clock so that its face shall indicate the time to within a small fraction of a second are even greater than the determination of the time in the first instance. The ordinary regulator varies with the temperature, the barometer, the thickening of the oil, friction, and other more obscure causes. In order to overcome these difficulties, the clock should be placed in a perfectly stable condition, the temperature should vary but a few degrees the year round, and its variations should not be sudden. The case should be either hermetically sealed, or else the rates should be accurately determined at different barometric pressures, and some method of compensation applied to the pendulum as the barometer varies.

In most large observatories, when it is desirable that the face of a clock should indicate absolute time, by a series of experiments the number of grains is determined which must be added to the pendulum bob to effect a fixed change of rate at any given temperature and barometric pressure. The observer then adds or subtracts a sufficient number of grains each day to render its rate insensible. Chronometers are much more sensitive to external influences, and, at the same time, there is no simple method of acting upon the chronometer balance so that its face shall indicate absolute time as in the case of the addition of weights to the pendulum of the clock. As is well known, from the construction of the chronometer balance, it can be adjusted so that, at two temperatures of the scale, the balance will vibrate exactly right. For all other temperatures, the chronometer will vary its normal rate. It does not, however, seem to be affected by barometric changes.

For these and many reasons, the pendulum clock is conceded to be the most accurate measure of time which we possess. And, as affording an excellent idea of the refinement necessary in its construction, in this connection we will refer briefly to the standard sidereal clock of the Royal Observatory at Greenwich, which may be found described in full in "Nature" for April 1, 1875.

"As in the galvanic system of registration of transit observations it is unnecessary that the clock should be within hearing or view of the observer, the new clock has been fixed in the Magnetic Basement, in which the temperature varies only a very few degrees during the course of the year. The pendulum is supported by a large and solid brass casting, securely fixed to the wall of the basement, and the clock movement is carried by a platform forming part of the same casting.

"The Astronomer-Royal adopted a form of escapement analogous to the detached chronometer escapement, — one that he had himself, many years before, proposed for use, — in which the pendulum is free, excepting at the time of unlocking the wheel and receiving the impulse. An ordinary mercurial seconds pendulum was first constructed, with a jar of larger diameter than is usually made; but this did not give satisfactory results. Notably it was found, whilst still on trial in the workshop, that when the temperature of the apartment was raised, the clock increased considerably its losing rate, which only slowly returned towards its previous value, showing quick action on the rod, and slow action on the quicksilver. This pendulum was finally discarded, and another made, employing entirely a metallic compensation. A central steel rod is encircled by a zinc tube, resting on the rating nut on the steel rod; the zinc tube is, in its turn, encircled by a steel tube, which rests at its upper end on the zinc tube, and carries at its lower end the cylindrical leaden pendulum bob attached, at its centre, to the steel tube.

"The weight of the bob is about twenty-six pounds. Slots are cut in the outer steel tube, and holes are made in the intermediate zinc tube, so as better to expose the inner parts of the compound pendulum rod to the action of temperature.

"For final adjustment of the compensation, two straight compensated brass and steel bars are carried by a collar, holding by friction on the crutch axis, capable of being easily turned on the axis. The bars carry small weights at their extremities. Increase of temperature should accelerate or retard the clock, according as the brass or steel lamina is respectively uppermost.

"On account of the uniform temperature of the Magnetic Basement, no opportunity has yet arisen for testing the efficiency of the apparatus. A contrivance is also added with the object of making very small changes of rate without stopping the pendulum. A weight slides freely on the crutch rod, but is tapped to receive the screw cut on the lower portion

of the spindle, the upper end of which terminates in a nut at the crutch axis. By turning this nut, the position of the small weight on the crutch rod is altered, and the clock-rate correspondingly changed. To make the clock lose, the weight must be raised.

"No contrivance was originally applied to the clock for correction of the barometric inequality; but the clock had not been in use many months before the extreme steadiness of its rate otherwise brought out with marked distinctness the existence of the inequality.

"It was easily seen that, for a decrease of one inch in the barometer reading, the clock increased its daily gaining rate by about three-tenths of a second. The Astronomer-Royal eventually arranged a plan for correction of the inequality, founded on the magnetic principle, long previously in use at the Royal Observatory for daily adjustment of the mean solar standard clock, and the apparatus has been applied to the clock by Messrs. Dent.

"Two bar-magnets, each about six inches long, are fixed vertically to the bob of the clock pendulum, one in front, the other at the back. The lower pole of the front magnet is a north pole ; the lower pole of the back magnet is a south pole. Below these, a horseshoe-magnet, having its poles precisely under those of the pendulum magnets, is carried transversely at the end of the lever, the extremity of the opposite arm of the lever being attached by the rod to the float in the lower leg of the syphon barometer. The lever turns on knife edges.

"Weights can be added to counterpoise the horseshoe-magnet. The rise or fall of the principal barometric column correspondingly raises or depresses the horseshoe-magnet, and increasing or decreasing the magnetic action between its poles, and those of the pendulum magnets, compensates, by the change of rate produced, for that arising from variation in the pressure of the atmosphere. As the clock gained with low barometer, it was necessary to place the magnets so that there should be attraction between the adjacent ends; that is, that they should be dissimilar poles.

"One other point may be mentioned in connection with this apparatus. The cistern in which the float rests is made with an area four times as great as that of the upper tube; so that for a change of one inch of barometer reading, the horseshoe-magnet is shifted only two-tenths of an inch, whilst the average distance between its poles and those of the pendulum magnets is about three and three-fourths inches: that is to say, the extent of variation of the position of the horseshoe-magnet should be a small fraction of the whole distance; because, with this condition, the effect produced on the rate by equal increments of distance is then practically uniform. The action of the apparatus on the Greenwich clock has, as regards correction of the inequality of rate, been quite successful; and further, the extent of the pendulum arc, which was before subject to a slight variation, is now very constant, and amounts (the total arc) to about 2° 33′ with scarcely any change."

We now ask — having obtained the correct time and means of keeping it from day to day, — how shall it be transmitted from the observatory to the railroad or the jeweller, without introducing the risk of any error? Electro-magnetism offers the only available solution. If we connect one pole of the battery with the point of suspension of a pendulum, and the other pole with a globule of mercury, so placed that when the pendulum is vertical a fine metallic point at the extremity of its bob is in contact with the globule, then, supposing that the pendulum rod is of metal, the circuit will be continuous when the pendulum is exactly vertical, and the circuit will be broken during the remaining time of the pendulum's vibration. Thus, we have a circuit which is complete once a second, and, very obviously, by placing a telegraphic sounder in that circuit, it will be heard beating in unison with the clock. By extending such a system, we could have any number of sounders beating in exact unison with each other and with the same clock. But one second could not be distinguished from another: so, to mark the beginning of each consecutive minute, and to mark the beginning of each consecutive five minutes, one pole of the battery, in making its connection with the point of support of the pendulum passes through a system of toothed wheels; so that, by means of one of the wheels, the circuit may be kept open during any particular entire vibration, and, by means of another wheel, may be kept open for twenty or thirty consecutive vibrations. By putting the proper number of teeth in each wheel, and having the vacant spaces at the proper intervals, the sounder can be made to omit any desired beat in each minute, and any desired number of beats each five minutes; and we may carry the method to the hours by a mechanical principle of the same nature.

Instead of the sounder, a little bell, worked by an electro-magnet, may be put in the circuit; and if the clock be then switched into circuit for a certain number of minutes each day, say at twelve noon, it makes a very simple and effective means of determining the error of any other clock within sound of the little bell.

We will say more of this presently. It would be safe to say, there have been a hundred different plans in which electricity has been proposed, either as a motor power for clocks, or else as a regulating agency. It is comparatively a simple matter to move a number of secondary dials so that each will indicate the same second that is indicated by the standard clock; and a number of dials with the proper electric appliances can be placed in the same circuit mentioned in the first case. In practice, however, such a system is found difficult to keep in working order when the circuit has any considerable length.

Electricity, as a motor power, has ceased to be employed in any of the prominent time systems; its greatest objection being in the fact, that any interruption of the current causes all the secondary dials to stop. We do not mean that secondary dials are not admirable for large buildings in which there are a number of rooms, each containing a dial. It is only in the case of long circuits that they are found troublesome. An effective public-time system requires that clocks situated at considerable distances apart shall indicate the same time, and that these clocks shall be free from interruption in case the current which passes through them all should, for any reason, be stopped. This is best accomplished by what is known as the Jones system, which we will endeavor to explain briefly. The wires from the two poles of the battery, the poles being grounded, terminate in two delicate springs, which are insulated from each other, and so placed that, when the pendulum is vertical, neither of the springs are in contact with it. If the pendulum is moved to either extremity of its arc of vibration, it presses against one of these slender springs; and the electric current — positive or negative, depending on which pole is connected with the spring — passes through the spring to the pendulum rod, which is connected with a wire which leads to a secondary clock, placed at any desired distance. Any clock may be used for this purpose, provided that the length of its pendulum is approximately the same as that controlled. Below the pendulum bob of this second clock, a horizontal bar is attached to the pendulum rod, at the two extremities of which several bar-magnets are fastened in place, with their similar ends pointing towards each other. Two small cylindrical coils are so placed that, as this pendulum vibrates, the two ends of this horizontal bar which holds the magnets are alternately encircled by these coils. The wire leading from the first clock to the second terminates in the first of these coils, and the current, after passing through both of them, is grounded. Obviously, as the pendulum of the first clock vibrates, it sends alternately positive and negative currents through these two coils, for we remember that one of the slender springs was connected with the copper, and the other with the zinc of the battery used. And consequently, when the pendulum vibrates to the extreme right, the electric current passes from the zinc through the slender spring which now is in contact with the pendulum rod, through the pendulum rod, through the wire leading from the point of support of the pendulum rod, to the coils in the second clock. After passing through the coils, the current is grounded. If the pendulum of the first clock was in contact with the spring on the left-hand side, the current would then proceed from the

copper, and we should consequently have a current of positive electricity traversing the same circuit as did the negative a second previous.

The action of these alternate positive and negative currents will be to retard the vibration of the pendulum of the second clock, if it is moving faster than the first, and to accelerate it if it is moving slower.

The above is a brief description of the system as applied to the Treasury clock at Washington, situated about one mile distant from the Naval Observatory in a straight line. As employed in England, the coil forms the pendulum bob, and two stationary magnets are fixed in a horizontal position to the clock case, so that the coil which is also horizontal passes over and circles each magnet successively.

Like poles of the magnets are placed towards each other. A galvanometer placed in the circuit and near the standard or first clock, indicates each second whether the entire circuit has been completed, and the distant clock or clocks are moving in exact sympathy with the standard. Any clock whose pendulum is approximately of the same length as the standard can be put into circuit and controlled, by adapting to its pendulum the magnets, and putting the coils in position. The strength of the current needed is very much less than for an ordinary telegraphic circuit of the same length; and the great advantage of the system is, that, should the circuit be interrupted, the clocks do not stop, but go on, merely accumulating their own errors, and obeying their own rates, — a very small inconvenience compared with the stoppage of the clock. The dropping of a time-ball, or the firing of a time-gun, are both very simple matters; and there are numbers of devices by which both can be accomplished by merely touching a key which electrically releases the ball, or causes a spark in the powder of the gun. We have endeavored to show in the preceding paper that the method ordinarily used for determining the time is inexact, and we have addressed ourselves particularly to pointing out how it is inexact, because from the jewellers must be derived a large share of support in an organized effort to obtain standard public time in any city. And we think they will agree with us, when we say that the care and expense of a well-equipped transit instrument, mounted in the most substantial manner, and with all the accessories for determining the slightest instrumental inaccuracies, together with the labor of making and reducing the observations, is too great for any single firm to assume, having merely in view the determination of correct time. The care and management should be lodged in an Astronomical Observatory. And in this observatory should be placed a mean-time clock of the finest construction, insulated as far as possible from climatic changes. The law

of the variation of its rate under the varying climatic conditions should be carefully studied; and each day the pendulum should be adjusted by adding or subtracting weights from the pendulum, or some other contrivance used, so that the clock will indicate true mean time as nearly as human art can make it. Every clear evening, observations should be made to determine the error of this standard clock. One wire from this clock should go to the jewellers' shops throughout a city, and should cause near each of them a sounder to repeat its beats each alternate second, omitting the 58th second and some particular number of seconds each five minutes. Another wire might lead to the pendulums of several clocks to be controlled on the Jones plan, in conspicuous places in a city. Either of these wires could be used to strike the fire-bells at any required hours of the day, or it might be advantageous to have a third wire which should fire a time-gun for the advantage of the shipping, and strike the fire-bells also. The advantage of such a plan on the score of economy, and the certainty of its results, are evident.

L. W.

HARVARD COLLEGE OBSERVATORY,
Nov. 1, 1877.

L. W.

Leonard Waldo.